MEDIUM-SCALE VEGETATION FUEL MAPPING IN THE LAKE BAIKAL BASIN

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ABSTRACT

A method of composing vegetation fuel maps (VF maps) at medium scale is explained along with the purpose of such maps. A vegetation fuel VF map for the Lake Baikal basin has been created as an example of using this method.

Keywords: prime conductors of burning, vegetation fuel map, current forest fire danger map.

INTRODUCTION

Medium-scale vegetation fuel (VF) maps are necessary for more accurate monitoring of fire danger in vegetated areas. The main function of such maps is to provide the basis for drafting maps of current fire danger at various drought severity classes. These medium-scaled maps of current fire danger are drafted by the application of VF maps onto maps of fire occurrence, which are useful for optimizing the planning the routes of aerial smoke patrols.

CLASSIFICATION OF VEGETATION FUELS

We started to develop methods for drawing VF maps in 1984 (Volokitina and Ryzhkova, 1984). The basis for this work was a system of VF classification. In Russia, the VF are classified by their contributions to fire incidence, spread, and behavior. N. Kurbatsky (1962, 1970) initiated the Russian VF system by classifying VF into seven groups:

1) moss, lichens, fine litter;
2) duff, humus and turf layers of soils;
3) grass, seedlings, and low brush;
4) large woody components (dead branches, snags, limbwood, slash);
5) understory saplings and shrubs;
6) green foliage and branches of living trees; and,
7) stems of trees and branches thicker than 7 mm.

On the basis of experimental and literature data on the characteristics of vegetation fuels, a second stage in VF classification has been developed. The VF complexes in the groups distinguished by Kurbatsky (1962, 1970) are divided into VF types (Sofronov and Volokitina 1985; Volokitina and Sofronov 1996). Then the classification of the first VF group (the prime conductors of burning or PCB) and division into subgroups, types and subtypes is more appropriately performed:

Vegetation Fuel Subgroups

Moss Subgroup: PCB types: Lichen (Lc) - lichens in forest floor vegetation, dry soil; Dry moss (Dm) - cover of true mosses over drained soil; Moist moss (Mm) - true mosses with polytrichum and sphagnum, poorly drained soil; Bog-moss (Bm_1) - polytrichum over bog or nearly bog soil, patchy boggy areas that may dry out during drought; Bog-moss (Bm_2) - sphagnum and hypnum over nearly-bog or bog soil.

Litter Subgroup: PCB types: Cured grass (Cg) - cover mostly dried or cured grasses or sedge; Loose litter (Ll) - loose litter (fallen pine needles and birch leaves, cured herbs); Compact litter (Cl) - compacted needles of fir, spruce, larch, or broad-leaved trees, consolidated loose litter late in summer; Non-conductor (Nc) - load of PCB fuel is below the critical level (0.05-0.20 kg m^2): (Nc_1) - smoldering fuels (litter, turf, duff) sustain ground fires only; (Nc_2) - PCB fuel absent or scarce (dunes, rock or pebble outcrops, plowed fields, etc.), no fire possible.

Those PCB fuels that become flammable at one drought severity class are attributed to the same PCB type, assuming the following standard environmental conditions: on a horizontal surface, under the canopy of a forest stand of middle canopy closure (0.5-0.7) with the foliage present. If actual drying conditions do not correspond to those described above they are non-standard and proper corrections should be applied.

We determine a drought severity class (DSC) based on the Nesterov index (Nesterov et al., 1968). The Nesterov index (DI) is based on the product of air temperature and the difference between air temperature and dew-point. Measurements are taken once each 24 hours, between 13:00 and 15:00 hours. DI is calculated by summing these values for previous days up through the current day, and is reset to zero if there is rain exceeding 2.5 mm during the previous 24-hour period. Relationships between DSC and DI (Sofronov and Volokitina, 1990) are:

DSC = 1 at DI < 300;
DSC = 2 at DI = 301-1,000;
DSC = 3 at DI = 1,000-3,000;
DSC = 4 at DI = 3,001-10,000;
DSC = 5 at DI = 10,001-30,000;
DSC = 6 at DI > 30,000

At DSC = 1, both lichens and dried grass PCB become flammable, at DSC = 2 loose litter and dry moss PCB types become flammable when the conditions for drying are standard. Forest fuel characteristics of the first subgroup (moss, lichens) are practically constant for the whole fire season. Those of the second (litter) subgroup may change their rate of drying due to such seasonal factors as decomposition of dead fuels, growth of fresh biomass (e.g. grass) in summer and its drying in the autumn. Therefore PCB types of the second subgroup can alter from one to another during a fire season.

For the remaining six groups, we suggest the first variant of their division into types. This should be improved in the future (Volokitina and Sofronov, 1996).

Pyrological Characteristics of Vegetation

There are two ways to describe pyrological characteristics of vegetation. In our opinion, the pyrological characteristics are those that can be used for evaluating fire danger, and predicting fire behavior and fire impact. The first approach to description is based on the typical characteristics of vegetation. For example, the fuel models of the US National Fire Danger Rating System (Deeming et al., 1972) or the method of Kurbatsky (1954) for classifying the typical pyrological characteristics of forest types. But the diversity of the vegetation is very high even though the number of categories (and respectively, number of typical characteristics) used is limited. As a result, the internal pyrological heterogeneity of the delineated vegetation categories will be high, and it will be impossible to characterize a particular area accurately enough for mapping on both a medium scale (1:500,000-1:1,000,000) and a large scale (1:25,000-1:50,000) (Sofronov and Volokitina, 1990).

The second approach is based on individual characteristics of vegetation (or forest) plots. We are inclined toward this approach as being more appropriate for representing the heterogeneity of fuel conditions on the landscape. Descriptions of characteristics of individual vegetation plots include evaluation of PCB types and the seasonal dynamics of the fuels, characteristics of other groups of VF, and patterns of moisture changes. These characteristics should be available on VF maps. Using this approach, we have developed methods for drawing VF maps on both medium and large scales (Sofronov and Volokitina, 1990). At present we have experimentally studied the pyrological characteristics of prime conductors of burning, such as the rate at zero wind speed, and unit energy release rate depending on the drought index. In our experiments we used the annular screen of Wright (1967) with a simple calorimeter for the investigation of the quantity and dynamics of heat emission during the combustion of vegetation from the forest floor.

METHODS

Two methods have been developed for drawing middle-scale VF maps. The first method we call “original” (or “autonomous”). It is based on using satellite imagery to delineate “Natural-Territorial Complexes” (NTC). Several NTC’s are integrated into “Categorical -Analogues” within natural regions, by satellite imagery of vegetation. Field studies are required on key plots to characterize NTC analogs, with the utilization of aerial photos. The second method for drawing middle-scale VF maps we call “conjugated.” Here, contours of existing maps of natural landscape types, or stocking levels, are used as the basis for drawing the VF map. Pyrological characteristics are attached to these contours based on the analysis of the legend of the base map, of other maps of the region, and also on other data on the VF for the region. In cases of shortages of data, field studies must be conducted.

The general process for developing these maps is:

1. Examination of material on general natural characteristics of the territory. This is aimed at revealing the character of its heterogeneity and separate natural zones. It necessarily must be carried out with the application of existing natural zoning systems, for example, a forestry one, and especially, a pyrological (wildland fire) zoning.

2. Choosing a base map. It is preferable to have a map of the most suitable scale, with the most detailed presentation of forest inventory plots (including detailed descriptions of the vegetation, especially forest floor vegetation). One requires the following additional information to develop a map of forest fuels:

a) general descriptions of the vegetation of the region of concern, and descriptions of the patterns of spatial distribution of the vegetation with regard to topography, especially for mountainous terrain;

b) the description of the biogeocoenosis types, both forest and non-forest ones;

c) data on the pyrological characteristics of forest types indigenous to the region; and

d) data on fire occurrence in the region.

3. Examination of satellite imagery. The aim here is to outline burned and felled areas, farmlands, and areas of sapling-pole deciduous stands, which are not displayed on the background map. If aerial photographs are available, interpretation of them will help to determine more precisely the character of vegetation modification.

4. The composition of a preliminary map: a) drawing of an outline map at a pre-determined scale; b) consideration of the legend of the background map and supplementary data materials, in order to develop the pyrological characteristics of forest inventory plot categories (here an assessment takes place of VF-PCB types and the dynamics of their seasonal change); c) designing of the fuel map legend; d) revision of the outline map and adding more details based on information taken from satellite imagery; e) coloring of the pre-map according to pyrological characteristics in accordance with the legend.

5. The selection of key areas. Based on the examination of the pre-map and supplementary material, key areas are selected for examination in the field (it is preferable to establish these areas in every natural zone). The key areas must meet the following conditions: be representative, accessible, and suitable for fieldwork. Relevant aerial photography must be obtained for the key areas.

6. Field examination includes: a) the selection of travel routes for observation and profiles; b) the pyrological description of sample points and profiles with the use of a special form. If stationary, fire danger buildup observations on some key areas (forest types) and fuel load measurements on some profiles are necessary; test plots are selected and supplied with meteorological observation points. Volokitina and Sofronov (1979) describe in more detail guidelines for the examination method.

7. Examination of the data from the field includes: a) checking whether the descriptions made on travel routes and the background map correspond with each other; if necessary, satellite images may be used to rectify the pre-map; b) revising the identification of PCB types (and their seasonal dynamics) indigenous to the present forest types and other area categories, based on route descriptions and the results of test ignitions; c) revising the table of the relationships between PCB types and forest types; d) rectifying the pre-map.

8. Drawing of the fuel map and its legend. The original draft of the map must follow common standards of map-making.

RESULTS

Using the conjugated method we have drafted a 1:1,000,000 scale VF map for the northern part and preliminary VF map based on GIS for the southern part for the Lake Baikal basin. Table 1 shows the legend of this map based on the legend of the map "Vegetation of South-East Siberia" (1972). Additionally, we used the information from a landscape map of the same scale and performed field studies. The VF maps shows, first of all, the prime conductors of burning (PCBs), their combinations and seasonal dynamics. Distributions of other VF groups (for example trees and shrubs) are marked by special symbols on the map.

EXPLANATORY COMMENT ON THE MAP

The least-prone PCB type, a non-flammable one with too low or zero fuel load, is common for mountain tundra and bald hills on high mountainous terrain. On flatter and lower terrain of the Ikat and Muya regions, thickets of dwarf creeping Siberian cedar (*Pinus pumila*) and boggy lands with sphagnum are common; therefore, a combination of loose litter and bog-moss PCB types is typical of those territories. The moist-moss PCB type, of relatively low fire danger, is typical for middle-mountainous terrain composed of Siberian cedar (*Pinus sibirica*) and *Abies* spp., the forest type is "low brush and true mosses;" such landscapes are situated along the shore at the foot of the Bargusin Mountains, also in the southern middle-altitude part of the Ikat mountain range and in the Ulan-Burgasy mountain range. The dry moss PCB types are intermediate

No. of plot on map	Type of PCB & categories of plots	No. of plot on map	Type of PCB & categories of plots
1	**Nc**, stony tundra	**31a**	**Dm**, P & L stands
2	**Bm**, moss-lichen tundra	**31b**	**Mm**, L & P stands
3	**Bm**, +dwB	**31c**	**Ll/Cl**, B stands
4	**Nc - Bm**	**35**	**Mm**, L stands
5	**Nc**, stony tundra	**36**	**Cl**,L & P stands
6	**Bm**, tundra	**38**	**Ll**, P & L stands + Rh
7	**Bm**, tundra	**39**	**Ll**, P & L stands
8	**Nc**, meadows	**40**	**Ll**, P & L stands
11	**Dm**, Ps sparse stands	**40a**	**Ll/Cl**, B & As stands
12	**Cl - Nc**, F sparse stands	**42**	**Ll - Cl**, B & As
14	**Mm**, F & Ps stands	**58**	**Cg/Bm**, bogs
14a	**Mm**, B & As stands	**64**	**Dm**, L sparse stands + dwPs
14b	**Mm**, As & B stands	**65**	**Dm**, L stands + dwPs
15	**Cl - Nc**,F & Sp stands	**66**	**Cl**, L stands + dwB
16	**Mm**, Ps & F stands	**67**	**Mm**, L stands
16a	**Dm**, P & L stands	**67a**	**Mm**, B stands
16b	**Dm**, L & P stands	**68**	**Mm**, L stands + dwPs
16c	**Dm**, B & As stands	**69**	**Mm**, L stands
17	**Mm**, Ps & F stands +dwPs	**70**	**Cl,**L stands
18	**Mm**, Ps stands + Rh	**71**	**Cl**,L stands + Rh
19	**Mm**, Ps stands	**71a**	**Ll/Cl**, B stands + Rh
19b	**Mm**, L stands	**72**	**Ll**,P & L stands +Rh
20	**Cl/Nc**, SP & L stands	**74**	**Bm**, L stands + dwB
21	**Dm**, L stands	**74a**	**Mm**, B stands
22	**Mm**, L & Ps stands	**76**	**Mm**, L stands
23	**Dm**, L & P stands + Rh	**77**	**Cg/Bm**, bogs + dwB
23a	**Ll/Cl**, B + Rh	**78**	**Bm**, bogs
24	**Ll**, P & L stands	**79**	**Cg/Nc**, meadows
24a	**Ll/Cl**, B stands	**87**	**Ll - Bm**, dwPs + tundra
25	**Cg/Ll**, L & P stands	**92**	**Cg/Ll**, steppe
26	**Cg/Ll**, P stands	**93**	**Cg/Ll**, steppe
27	**Ll - Lc**, P stands	**94**	**Cg - Nc**, steppe
28	**Dm**, Sp sparse stands + Rh	**95**	**Ll/Cl**, steppe
29	**Mm**, F & Ps stands	**96**	**Ll/Cl**, meadows
29a	**Dm**, P stands	**97**	**Cg/Nc**, meadows
29c	**Ll/Cl**, B & As stands	**98**	**Ll/Cl**, meadows
30	**Mm**, Ps & F stands	**100**	**Cg - Nc,** steppe
30a	**Mm**, L & P stands	**101**	**Ll - Nc**, steppe
30b	**Mm**, B stands	**103**	**Ll**, meadows
31	**Mm**, Ps & Sp stands	**104**	**Cg - Nc**, bogs
		106	**Ll -Cl**, steppe

Table 1. The legend of the VF map based on the legend of the map "Vegetation of South-East Siberia," 1972. **Notes:** Type of PCB (prime conductors of burning): 1) mossy PCB Subgroup: **Lc** - Lichen, **Dm** - Dry moss, **Mm** - Moist moss, **Bm** - Bog-moss; 2) litter PCB Subgroup: **Cg** - Cured grass, **Ll** - Loose litter, Cl **-** Compact litter, **Nc** - Non-Conductor. **Nc - Bm**- combination of PCB of the area; **Ll/Cl**- seasonal changes of PCB (Ll **-** in spring and autumn/**Cl**- in summer). Species: P - Pine, Ps - Siberian Pine, F - Fir, B - Birch, As - Aspen, Sp - Spruce, L - Larch. Shrubs: dwB - dwarf Birch, dwPs - dwarf Siberian Pine, Rh - Rhododendron.

in fire danger. These, which get ready to burn under conditions of the second fire danger class, are typical of sparse larch stands (low brush and mosses) forest types with the forest floor composed of brush and moss, situated on the ridges of the Southern Muya mountain range and in mid-altitude mountain valleys. In spring and autumn, the fire danger is in the dried grass PCB of the dead fuels PCB subgroup. It is typical of the vegetation of the closed Bargusin hollow and the Lower Angara hollow. On steppe-like terrain, this PCB type usually alters from the live grass and cured grass PCB type in spring to the loose litter or even non-flammable

PCB type in summer in response to seasonal drying. The loose litter PCB is also typical of pine stands that surround the Bargusin hollow; the compact litter PCB is typical of the larch stands of this area.

CONCLUSIONS

The main function of medium-scale vegetation fuel maps is to serve as the basis for drafting maps of current forest fire danger at various drought severity classes (DSC). These medium-scale maps of current forest fire danger can be drafted by the application of VF maps onto maps of fire occurrence and are useful for optimizing the planning of aerial patrol routes.

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